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Request for grant of a patent

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1	Your reference	SPG/P36077
2	Patent application number	**9907145.8**
3	Full name, address and postcode of the applicant	FTL Seals Technology Ltd Bruntcliffe Avenue Leeds 27 Business Park Morley Leeds, LS27 0TG United Kingdom
	Patents ADP number	763130 2001
	State of incorporation	England and Wales
4	Title of the invention	Apparatus
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6 Priority applications	Country	Priority App No	Date of Filing

7	Parent application (eg Divisional)	Earlier Application No	Date of Filing
8	Statement of Inventorship Needed?	Yes	
9	Number of sheets for any of the following (not counting copies of same document)		
	Continuation sheets of this form		
	Description	11	
	Claims	2	
	Abstract		
	Drawings	3	
10	Number of other documents attached		
	Priority documents		
	Translations of priority documents		
	P7/77		
	P9/77	1	
	P10/77		
	Other documents		
11	I/We request the grant of a patent on the basis of this application. Signature S.P. Gilholm Date 29 Mar 1999		
12	Name and daytime telephone number of person to contact in the United Kingdom	STEVE GILHOLM +44 113 2258350	

DUPLICATE

APPARATUS

This invention relates to a novel apparatus for use in connection with pipe cleansing and monitoring systems. In particular the invention relates to a novel suspension system for use in relation to pipeline pigging apparatus.

Both subsea and land pipelines for the transportation of various products are subjected to frequent internal cleaning and inspection. This process, known as "pigging", is effected by inserting a "pig" into the pipeline. The "pig" usually comprises a longitudinal shaft upon which is mounted at least one pig disc and at least one drive disc.

In a cleaning pig the diameter of the pig disc is such that it creates a positive interference between the inner walls of the pipe and the outer surface of the pig disc. Motion is induced in the pig vehicle due to the flow of the product, e.g. oil or gas, in the pipeline against the drive disc. Thus, the pig progresses along the pipeline, the pig disc scraping the sides of the pipe wall causing a cleaning/scouring motion.

Pipeline cleaning technology up to this point has relied upon a pig unit consisting of discs connected by spacer rings via their longitudinal axis. The weight of the pig is supported on "hard" guide discs, whilst the cleaning is carried out by "soft" sealing discs.

Inspection pigs operate along similar lines, but because there is no necessity to scrape the internal walls of the pipe, inspection pigs can be mounted on individually sprung wheels. They usually comprise a longitudinal shaft provided with one or more guide discs and are propelled in a similar fashion to a cleaning pig. An inspection pig will also be provided with monitoring equipment, for example, gauging or odometer wheels, to enable the detection of structural flaws in the pipes.

However, both types of pig currently used suffer from the disadvantage that they cannot be run concentrically down a pipeline. For cleaning pigs this can result in uneven wear of the guide and/or sealer discs. Even with a wheeled pig, because, *inter alia*, the wheels are independently sprung, the weight of the pig will usually rest on a fraction of the wheels at any given time. This will cause the pig to run off centre and cause uneven wear on the wheel.

Thus, there has long been a desire to produce a pig which reduces wear, increases the pig's life span and, in the case of a detector pig, minimises detection errors. Moreover, there is an increasing desire to manufacture a pig which is capable of being used in pipelines of varying diameters, such as, for example, that which is being laid as part of the large Åsgard transport line in the Norwegian Sea.

We have now surprisingly found a novel suspension unit which is suitable for use with a pig assembly and which overcomes or mitigates the aforementioned disadvantages. The suspension unit also permits the manufacture of a pig which is capable of functioning in multidiameter pipelines. Previously, it has only been possible to manufacture a pig which can adjust between say 40 and 42 inches, whereas the novel suspension systems permit variation between, for example, 28 and 42 inches.

Thus, according to the invention we provide a pig suspension system adapted to fit a pig shaft and comprising a plurality of wheels characterised in that the wheels are concentrically mounted around a piston which is operable in a direction coplanar with the pig shaft.

The piston used in the suspension unit of the invention may comprise any conventionally known type of piston, such as a hydraulic piston. However, a preferred piston is a spring loaded piston.

The wheel and piston arrangement will preferably comprise a plurality of wheels wherein each wheel is supported by a radially mounted suspension arm which itself is connected to a piston mounting block by a pivot pin. The suspension arm is pivotally connected to a tie rod. The end of the tie rod distal to the suspension arm being connected via a pivot pin to the piston. The piston assembly is such that the piston operates in a direction coplanar with the pig shaft. Thus in operation the piston will generally be acting in, for example, a horizontal plane and the tie rod will convert the piston movement to radial movement of the suspension arm and consequently the wheel.

As previously mentioned, one significant advantage of the suspension unit of the invention is that it provides centre line running of the pig. Centre line running is achieved because there is effectively a constant loading on an individual wheel. When the suspension arm is in a substantially vertical position the loading on the wheel will be in the region of 259 kg. With a conventionally sprung wheel, the loading can increase significantly if the diameter of the pipe varies and will usually lead to failure of the wheel by typically stripping of the roller. However, with our novel suspension unit comprising a spring loaded piston, in conjunction with suspension arm geometry, the spring compresses giving an increase in force, but controlled load of the wheel. Thus it is a particular aspect of this invention which provides a pig suspension unit which has substantially constant wheel loading. In an especially preferred embodiment we provide a suspension unit in which the wheel loading can be kept between the limits of 4,000 and 13,000 N. Thus, for example, the wheel loading in a 28 inch diameter pipe will be between 4,000 and 7,000 N; for a 42 inch diameter pipe the wheel loading will be between 6,000 and 10,000 N.

The wheel loading can be varied depending upon, inter alia, the nature and tuning of the piston. Thus, in the case of a spring loaded piston, the spring rate may be varied depending on each application. If the weight of the pig changes, through, for example adding parts, then the springs can be tuned which will modify the spring rate. Thus, by way of example only, the spring rate may be between 10 and 70

N/mm, preferably between 20 and 60 N/mm. Furthermore, the wheel loading can be altered if the spring is adjusted. The spring pre-loading is a spring rate of 50N/mm and 27.5mm pre-loading and may be between 20 and 50 mm. A preferred arrangement will be variable depending upon application.

The suspension can be tuned by adjusting the position of the tie rod pivot point on the suspension arm. Thus the pivot point may be varied depending upon, *inter alia*, the pig weight and the performance required of the pig and which would be understood by one skilled in the art. The geometry of the tie rod connection to the suspension arm will also vary depending upon the application, although it is related to the spring rate. For example, there will be a maximum continuous wheel loading for a chosen wheel and the geometry will be "balanced" by adjustment of the spring rate.

In a further preferred embodiment, the suspension arms of the wheel assembly is offset from the axis of the pig shaft. This enables the wheel assembly, and hence the pig, to rotate whilst travelling down a pipe. This has the advantage that there is an evening out of the length of time any wheel experiences maximum load and, more importantly, it reduces and evens out the wear on the sealing discs. Thus the suspension unit may be offset between 1 and 3° of the pig shaft axis and preferably 2° of the pig shaft axis.

The number of wheels provided in a suspension unit of the invention may vary depending upon the size and weight of the pig. In a preferred embodiment a pig will be provided with at least two wheel assemblies comprising the suspension unit of the invention, e.g. a front and a rear set. Although, for articulated pigs more than two sets may be used. Although each set may comprise any number of wheels, preferably supported by up to eight wheels may be used in any set, although this number may be varied according to the dimensions of the pig. All the wheels in a single assembly are preferably connected to an appropriate piston although it is within the scope of the invention that some of the wheels may be conventionally mounted. The wheels

are generally arranged so that any wheel is mounted with another wheel on the opposing side of the shaft.

However, in a preferred embodiment a pig is provided with two sets of wheels, substantially one at either end of a pig shaft. We have found it particularly advantageous when operating a pig with at least two wheel assemblies to have the wheels of one assembly offset from the plane in which the wheels of a second assembly operate.

The tie rod used in the suspension system of the invention may incorporate a turnbuckle. The turnbuckles may be provided separately to the suspension. However, as an aspect of the invention we provide a turnbuckle for use in connection with a tie rod and a suspension system as herein before described.

The novel wheeled pig is advantageous in that, *inter alia*, in all spheres of operation it retains the centre line, unlike conventionally known pigs. Thus, as a consequence, it reduces and evens out the wear on the discs and increases efficiency. Thus, in one aspect of the invention, conventionally used discs may be included in the pig system. Such discs usually comprise substantially circular polyurethane discs, "hard" discs being used to support the pig and "soft" discs to scrape the inner surface of the pipe. However, for use in relation to dual diameter pipes, a collapsible disc may advantageously be used, such that the disc may, for example, fold or unfold to reflect the dimensions of the pipe.

In a further alternative embodiment, the pig of the invention may be provided with conventional detector systems, for example gauges, odometer wheels, thus enabling the pig to be used as a detector pig and enabling the manufacture of semi-intelligent cleaning pigs.

The invention will now be illustrated by way of example only and with reference to the accompanying drawings in which,

Figure 1 is a cross section along the vertical axis A - A of the suspension unit shown in Fig 2;

Figure 2 is an end view of the suspension unit according to the invention; and

Figure 3 is a perspective representation of a pig provided with two wheel assemblies comprising the suspension unit of the invention.

With reference to Figure 1, a wheel assembly (5) comprises a wheel (9) rotatably mounted on a suspension arm (10). The suspension arm (10) being pivotally mounted to the body mounting block (11). The suspension arm (10) is also provided with a tie rod (12), which tie rod (12) is provided with a turnbuckle (12a) and is pivotally connected at one end (13) to the suspension arm (10) and at the other end (14) to the piston mounting block (11a). The end (14) of the tie rod (12) is slidably connected to the housing via a piston assembly (15) comprises a spring (16) mounted on a piston shaft (17), the spring (16) resting on a fixed bulk head (18) of the piston chamber (19) and biased against the other slidable bulk head (20) of the chamber (19).

Referring to Figure 2, a plurality of radially positioned wheels (9) are each rotatably held by a suspension arm (10), the suspension arm (10) being connected to a piston (17) by a tie rod (12).

With reference to Figure 3 a pipeline cleaning pig (1) comprises a longitudinal shaft (2), radially mounted cleaning discs (3 and 4) and wheel assemblies (5 and 6) at the forward end (7) and distal end (8) of the shaft (2).

In operation the piston biases the tie rod and thus the wheel to fit snugly against the wall of a circular cross section pipe.

Example 1

<u>Suspension Geometry and Force Calculations</u>

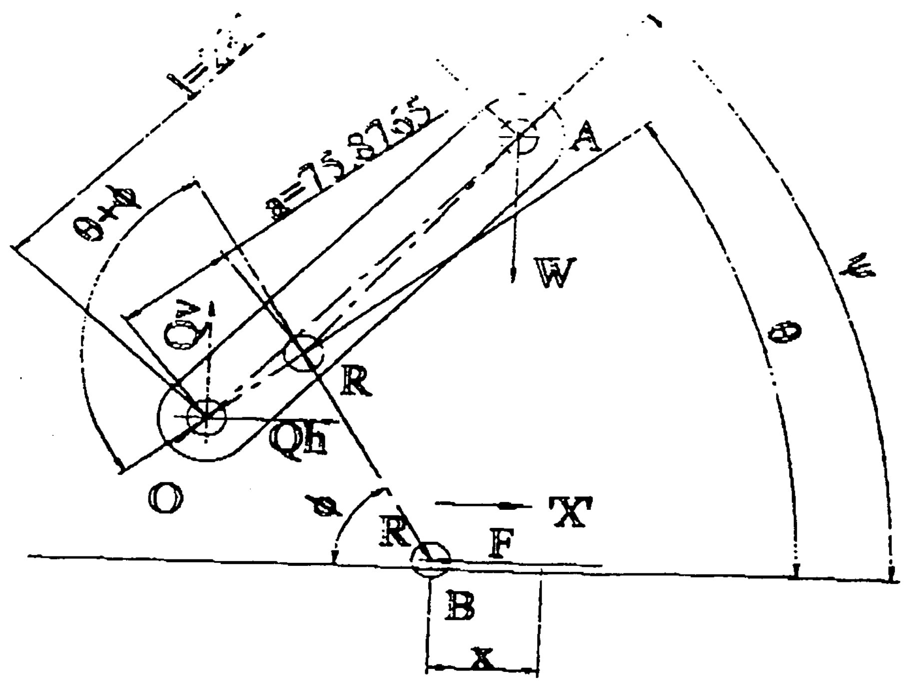


Figure A **Centreline Suspension Geometry**

Note: Point B is constrained to move horizontally by the inner piston assembly, whilst the arm pivots about point O.

W= force at wheel(s)
R= load in turn-buckle
F= Spring (piston force)
Qh= Hor. force on mounting
Qv= Vert. force on mounting

a= Effective link length 75.8765mm
l= overall arm length
φ= angle between turnbuckle and piston CL
θ= angle between pivot to body mounting block CL
ψ= Angle between arm CL and piston CL
α= Difference between θ and ψ; constant = 8.7175°

Take moments about position O for link AO

$W*l*\cos\psi = R*a*\sin(\theta+\phi)$ a)

but resolving R horizontally at B we get

$R*\cos\phi = F$ b)

or

$R = F/C\ s\phi$ c)

substitute c) into a)

$W*l*\cos\psi = F/\cos\phi * a*\sin(\theta+\phi)$

rearranging gives

$W = F^*a^*\mathrm{Sin}(\theta-\phi)/L\,\mathrm{Cos}\psi.\mathrm{Cos}\phi$ (3)

simplifying gives

$W = F^*k$ where $k = a^*\mathrm{Sin}(\theta-\phi)/L\,\mathrm{Cos}\psi.\mathrm{Cos}\phi$ (4)

Referring to Figure 2 below and calculating k we get NB $\theta = \psi - 8.7175°$

Table 1 k For Varying Suspension Positions

Position	ψ	θ	ϕ	k	Dia over Wheels
	α	8.7175			
1	47.0182	38.3007	58.5278	0.5029	
[redacted]					
3	37.2031	28.4856	51.9249	0.3817	
4	30.0709	21.3534	47.3345	0.3132	
5	23.4220	14.7045	43.2047	0.2587	
6	17.0933	8.3758	39.4099	0.2122	
7	10.9736	2.2561	35.8724	0.1706	
[redacted]					
9	1.9034	-6.8141	30.8851	0.1114	
10	-1.1669	-9.8844	29.2709	0.0913	

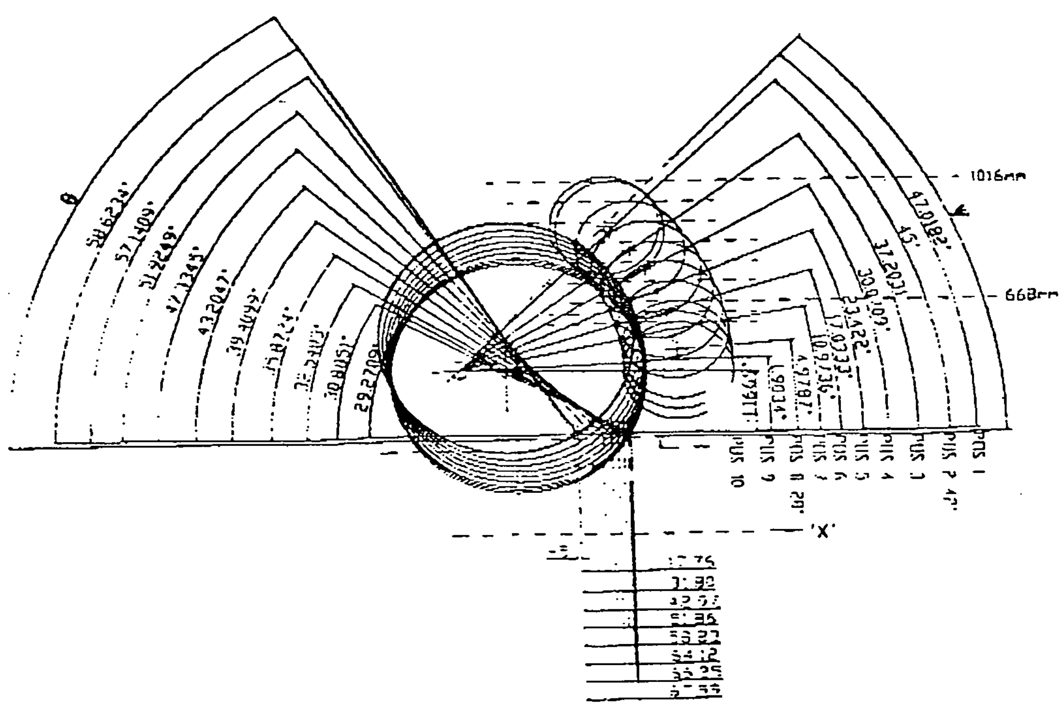
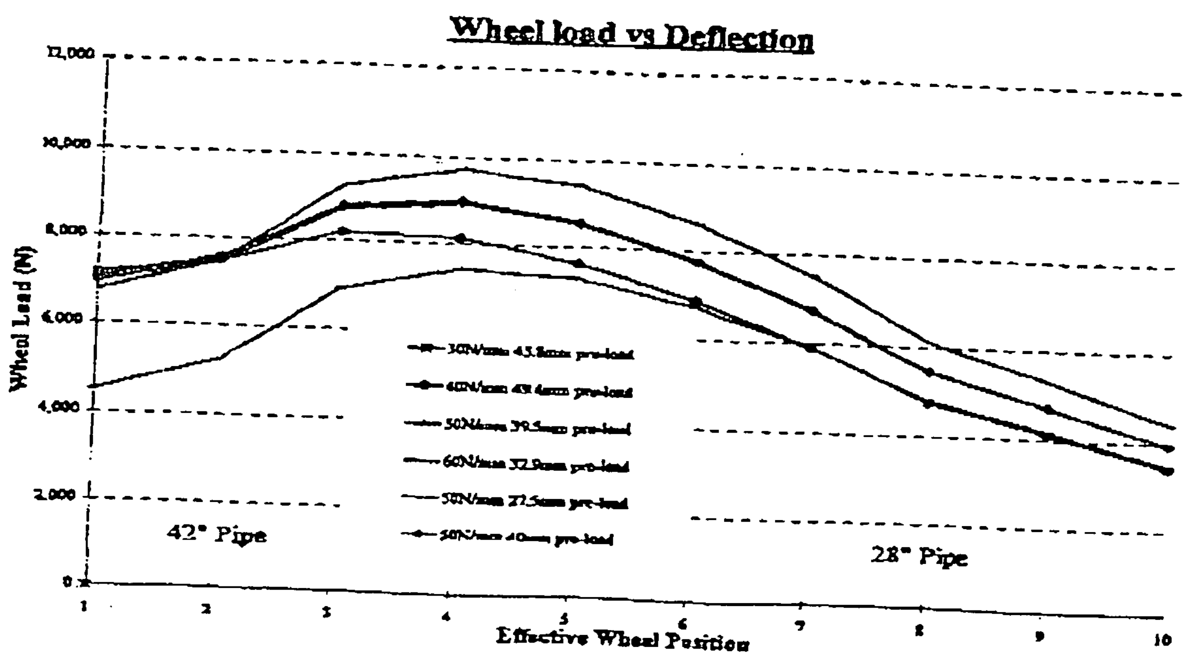


Table 2 Wheel Loads

Position	ψ	θ	φ	κ	Dia over Wheels	x (mm)		W (N)				
	α	4.7175										
							λ N/mm	40	50	60	50	50
							p mm	49.4	39.5	32.9	27.5	40
1	47.0182	38.3067	58.5278	0.5029		-5.00	[illegible]	7143	6942	6741	4526	7041
2	[illegible]	[illegible]	57.1409	[illegible]	[illegible] (42")	0.00		7209	7300	7500	[illegible]	7591
3	17.2831	28.4856	51.9249	0.3817		12.76		8201	8743	9286	6800	8818
4	30.0709	21.3534	47.3345	0.3132		31.80		8137	8934	9731	7488	8996
5	23.4220	14.7045	43.2047	0.2587		42.97		7645	8534	9423	7284	8585
6	17.0933	8.3758	39.4099	0.2122		51.86		6876	7757	8638	6737	7799
7	10.9736	2.2561	35.8724	0.1706		58.83		5907	6709	7512	5890	6743
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	6118	[illegible]	5490
9	1.9034	-6.8141	30.8851	0.1114		66.25		4121	4712	5302	4177	4733
10	-1.1669	-9.8844	29.2709	0.0913		67.99		3430	1927	4424	3488	3545

Of the above options only the 50N/mm spring is suitable to fit within the space constraints of the pig body. With this rate the weight 7,500N of a section will be adequately supported at 42" but only 72% supported at 28". However the actual weight of the vehicle is now know to be a total of 1,000kg or 5,000N per module so the configuration is adequate even at 28". Rather that operate with near maximum spring pre-load, 27.5 mm was chosen as giving a better match to support the actual vehicle weight. The final column show the affect on wheel loading if the springs are adjusted to their maximum pre-load setting of 40mm. Figure 3 shows the data in from the Table 1 in graphical form.



Example 2

Suspension Modules Material Selection.

The Main Body of The Modules.

The material selected for the main body of the suspension modules is a drawn over mandrel (DOB) cylinder tube ref. ASTM A513 grade 1026. The drawn tube has a tensile strength figure of 585 N/mm^2. The other components fabricated onto the body are BS970:080M50 (EN43A).

The finished body is phosphated all over and the external surfaces are xylan 1070 coated.

The Piston.

The material selected for the piston is BS970:080M50. The piston comprises a main tube and a welded in flange of the same material. The finished piston is phosphated and xylan 1070 coated.

The Suspension Linkage Mechanism.

The majority of the suspension linkage components are manufactured from BS970:708M40 which is heat treated to condition R. This gives a tensile strength 700/850 N/mm^2 and a hardness value of 201/255 HB. The components that are not manufactured from this material are the suspension arms due to the requirement to be able to have simple fabrication done, are manufactured from BS970:080M40 (EN8). All suspension linkage components are phosphated and xylan 1070 coated.

Suspension Springs.

The spring rate and overall working parameters were passed on to our chosen spring manufacturer.

Discussion indicated that the springs should be manufactured from BS1429:735A50 which is hardened and tempered to 48/50 HRC.

Following heat treatment the springs are shot peened and zinc plated and passivated.

Wheel Assembly.

The wheel assembly components are manufactured form stainless steel AISI No 303 (hub) and 316 (rest).

Stainless 303 was chosen for being non-magnetic when used in an inspection vehicle environment whereas 316 was chosen for its extra resistance to sea water.

The tyre material is a polyurethane which has a hardness rating of 92-95 Shore A.

The bearing elements are sealed units and a rotating labyrinth seal in stainless steel ref 1.4310 is positioned in two places.

Claims

1. A pig suspension system adapted to fit a pig shaft and comprising a plurality of wheels characterised in that the wheels are concentrically mounted around a piston which is operable in a direction coplanar with the pig shaft.

2. A pig suspension system according to claim 1 characterised in that the piston is a spring loaded piston.

3. A pig suspension system according to claim 1 characterised in that each wheel is supported by a radially mounted suspension arm, the suspension arm being provided with a pivot pin connected to a suspension mounting.

4. A pig suspension system according to claim 3 characterised in that the suspension arm is connected at a point along its length to a tie rod, the tie rod being connected via a pivot pin to a sliding piston assembly.

5. A pig suspension system according to claim 1 characterised in that it provides substantially constant wheel loading.

6. A pig suspension system according to claim 1 characterised in that the suspension arms of the wheel assembly are offset from the axis of the pig shaft.

7. A pig suspension system according to claim 6 characterised in that the suspension arms are offset by between 1 and 3° of the pig shaft axis.

8. A pig suspension system according to claim 7 characterised in that the suspension arms are offset by 2° of the pig shaft axis.

9. A pipeline pig comprising a suspension system according to claim 1.

10. A pipeline pig according to claim 9 provided with at least two wheel assemblies.

11. A pipeline pig according to claim 11 characterised in that the wheels of one wheel assembly are offset from the plane in which the wheels of a second assembly operate.

12. A pipeline pig according to claim 9 adapted to be a monitoring pig.

13. A pig suspension system according to claim 1 characterised in that the cleaning disc is of a collapsible nature enabling the pig to be used in multidimensional pipes.

14. A turnbuckle for use in connection with a tie rod and a suspension system as herein before described.

15. A pig suspension system substantially as hereinbefore described with reference to the accompanying description and drawings.

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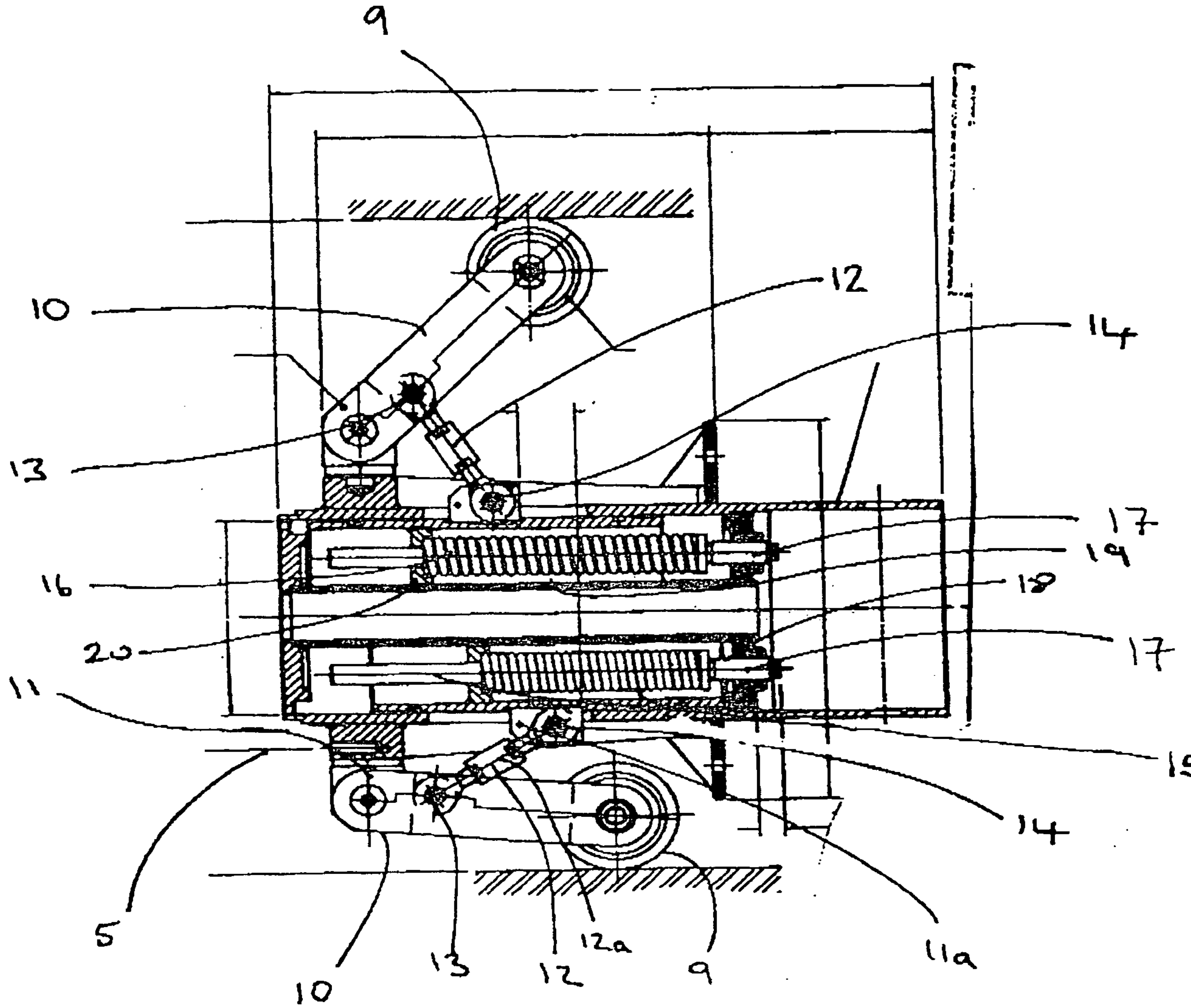

Fig. 1

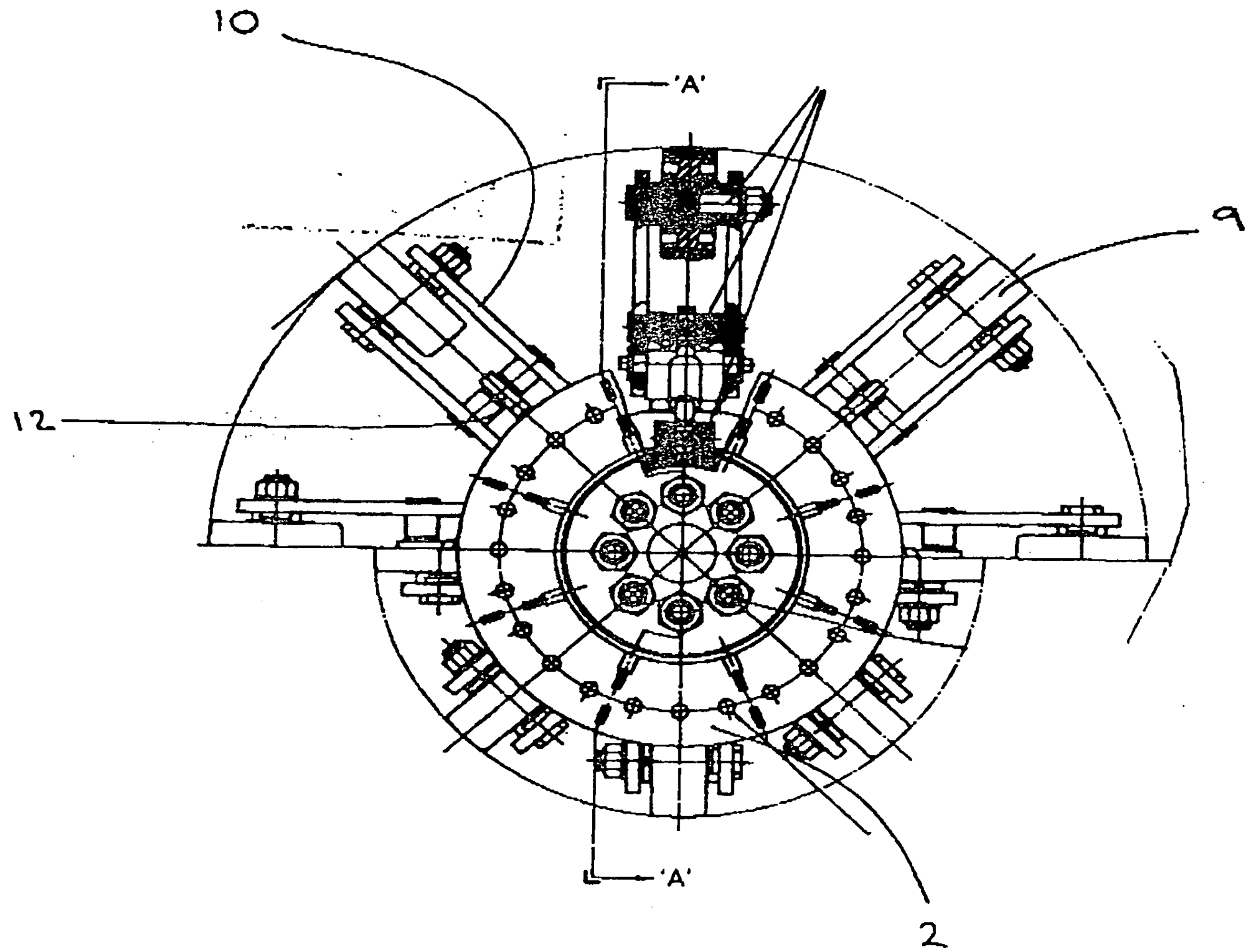

Fig. 2

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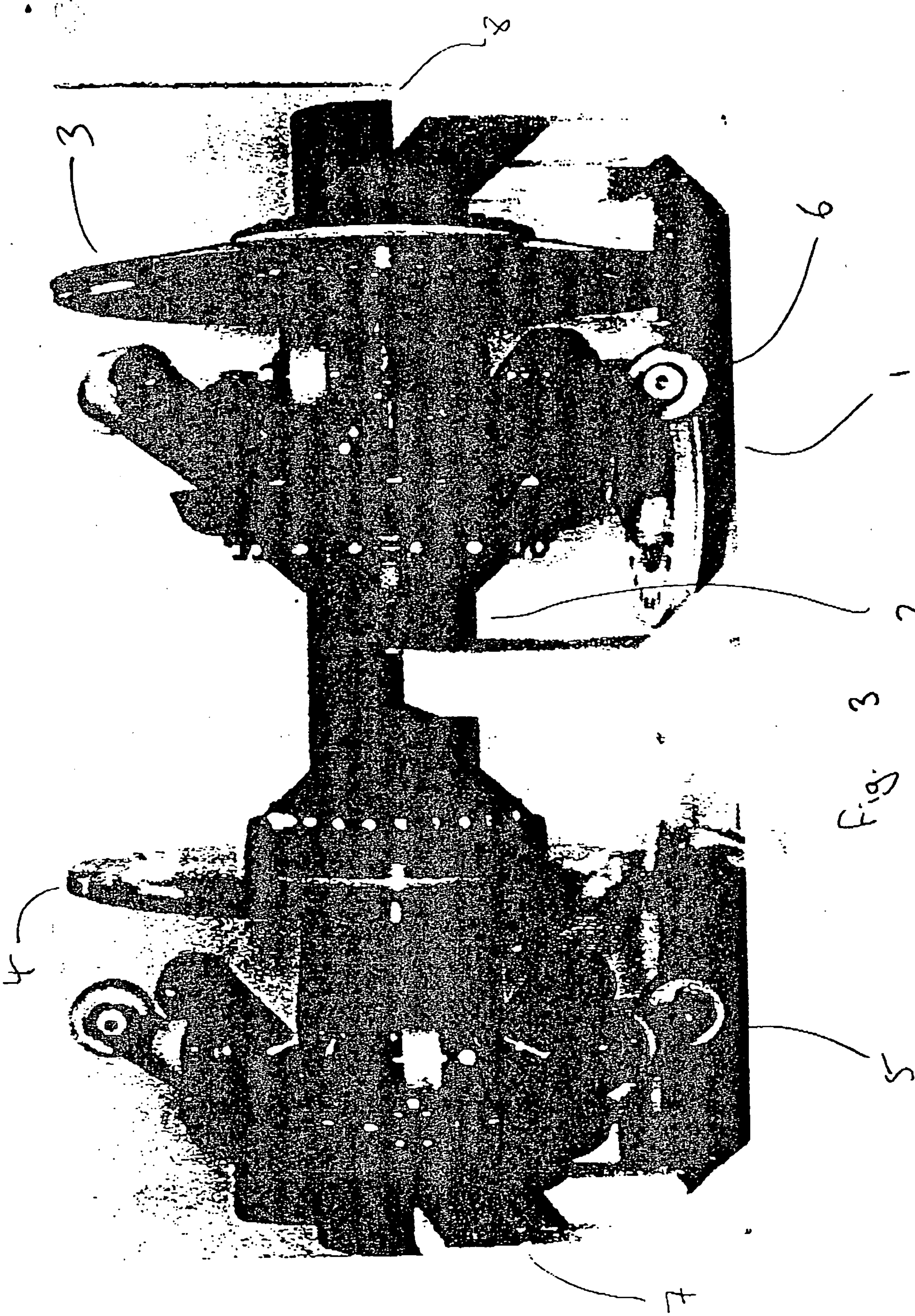

Fig 3

28/3/2000

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